Car Crash Detection and Emergency Alerts (Sos)

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Abstract
Human loss by road accidents has been a devastating issue, which possess negative implications on the socio-economic development of the societies. Most developing countries are recording higher volumes of fatalities whenever a road accident occurs due to the lack of a proper and quick system that reports accidents to the emergency services for an immediate rescue. Moreover, the chances of survival of any casualty of an accident is mostly dependent on how quick the emergency medical services arrive at the scene and quickly reaches the nearest hospital with the victims for treatment. However, these emergency vehicles are sometimes delayed by heavy traffic en route to and from the accident scene. This paper introduces a robust automatic vehicle accident detection and alert system, which uses an accelerometer to detect the tilting and the crashing of the vehicle, sends the Global Positioning System (GPS) location of the accident scene to intended security, medical and family contacts. The proposed design achieved a turnaround response, which is faster than conventional rescue system without these features. Hence, saving more lives as possible through technology.

INTRODUCTION

Road transport is increasingly popular in the world. However, road accidents especially in cities and towns are rapidly increasing to an uncertain level, which is devastatingly affecting the socio-economic development of people. The effects include the huge costs of losing livelihoods, leaving families destitute, and infrastructural damage costs and losses. Measures to prevent human loss whenever an accident occurs are among the top priorities to be addressed in this paper. Most governments in all these developing countries, including the government of South Africa, are embarking on a vision to work on the best way possible to reduce the occurrence of these road accidents by raising awareness and offering efficient road safety lessons. Realistically, in most cases, accidents occur unexpectedly or mistakenly thus the main challenge has been timeliness in reaching the victims involved in an accident and taking them to the hospital for treatment. This problem is normally caused by the provision of late reports or even the conveyance of insufficient information about the accident including the location of the scene to the emergency services or rescue authorities [1]. Hence there is a greater need to introduce and establish an internet of things (IoT) related automated system used to detect an accident, notify the nearest emergency services to offer immediate medical services to the victims, and promptly notify the immediate family member of an effective rescue system to save human lives. Hindrances such as the traffic jams, which tend to delay the emergency vehicles such as ambulances, rescues authorities, fire brigade, and police

vehicles are to be discussed in this paper.
The improved smart traffic light has got some eminent features of decongesting all lanes with a higher density of traffic in first preference to others. Most importantly, with regards to this project, traffic lights are designed to pave way for emergency vehicles using Radio Frequency (RF) communication. Emergency vehicles are responsible to offer immediate help in an accident or disaster at any given time. In such life-threatening scenarios, these vehicles are allowed to breach all road rules so to pave a quick way for that vehicle to reach its destination in time. However, these emergency vehicles face a big challenge of getting delayed to reach their intended destinations by traffic congestion especially in cities and towns during peak hours. Whenever these emergency vehicles delay reaching any destination in a real life-threatening situation such as road accidents or fire, there is a greater chance of losing lives and property loss. In other instances, the emergency vehicles are also involved in road accidents because they are allowed to break the traffic regulations of high speeding and overriding the red traffic light, whenever they are in the emergency mode [2]. Therefore, a more efficient system is desired as presented in this paper.
The rest of this paper is arranged as follows: the literature review on published works, design of the automatic vehicle accident detection and rescue system, results and discussion, and conclusion are in Sections II, III, IV, and V, respectively.

LITERATURE REVIEW

A. Accident Detection Systems

In most parts of the developing countries, the automatic accident detection system has not been established. The accident can only be reported to the nearest police station when there is somebody who has witnessed the accident occurring in their sight or anyone passing by the scene. By so doing, most people lost their lives since this process is not so effective in offering an immediate rescue required, as it all depends on the good attitude of the witness. In most cases, if the accident tends to occur at night or during harsh environmental conditions such as thunderstorms, snow or fog human movement is limited hence people perish in accidents without being noticed. More so, if a fatal accident occurs in the middle of a jungle, mountain range or desert usually it takes ages to notify the emergency services thus resulting in the loss of human lives. Thus, the current existing system of notifying the police about any accident, which have occurred is by the witness of a third party in most cases [5]. According to [6], an intelligent accident detection system was designed to sense a change in the original position of the vehicle using an accelerometer however a notification to the nearest hospital is only sent if the heartbeat sensor is activated. The signal from the accelerometer and the heartbeat sensor is sent to the driver's phone via Bluetooth and thereafter the driver's phone will notify the nearest health facility and the closest relatives via a text message. However, this design might be affected by phone glitches or even when the battery of the phone dies the process is terminated.
Another approach of accident detection was investigated by [7], using GPS to keep track of the speed of a vehicle. A microcontroller is used in conjunction with the GPS module to compare in a period of a second, the current and the preceding velocity of the vehicle. The system presumes an accident to have occurred whenever the speed of the vehicle is under the set or threshold speed, thus it notifies with the exact spot of the scene of the accident to the responsible rescue services authorities. This system has a major drawback of ineffectiveness as vehicle accidents are not only caused by over speeding. Hence it is not a realistic and recommended method for effective accident detection.

The authors in [8], designed a vehicle accident detection system based on Message Queueing Telemetry Transport (MQTT), which is used together with a vibration sensor connected to a NodeMCU microcontroller using Wi-Fi. All vibrations data collected from the sensor of the vehicle are consistently uploaded on cloud unless non-typical vibrations, which surpasses the set value are captured; then, an alert message is sent via email to the next of kin registered on the system. The absence of GPS makes it difficult for the rescue team to locate the scene of the accident thus elongating the rescuing time, which increases a higher chance of the casualty to lose their lives. Also, the use of emails could be slow in rescuing the victim of the vehicle accident.

Moreover, a smart phone can be programmed to detect the vehicle accident using Mamdani Fuzzy Logic, thus uploading all the information to the Data Centre. Upon detection an alert notification is sent to the registered relative numbers and the Communal Safety Authorities. The effectiveness of the rescue process solely relies on the proximity of the Communal Safety Authorities and the scene of the accident as presented in [9].

B. Smart Traffic Controller Systems

Most emergency vehicles in developing countries use display lights and sirens to provide a sound signal for other traffic to make a way for that vehicle. However, this method is not efficient especially during peak hours (early in the mornings or late evenings) when most roads are heavily congested [10]. A smart traffic system was designed to aid emergency vehicles especially ambulances whenever it approaches a traffic junction in [11]. An android device is used from the emergency vehicle to interrupt the signal timing cycle of the traffic lights controlled by a microcontroller AT89S53 via Bluetooth so to prompt a green light signal for the emergency vehicle's lane [11].

The work in [12] designed a traffic light signal in a different dimension using the laser diode and photo diode to control the traffic density. Thus, the green signal is offered in first preference of the lane with the heaviest density whilst other lanes are on hold by a red signal.

A more complicated approach of traffic management, which comprises of the use of radio frequency reader (RFID) tags and 8 barricades (2 per each lane) established before the zebra crossing lines so to block law breaking drivers who tends to override the red robot. In each lane, a RFID reader is installed on the wayside such that when an emergency vehicle passes by, the radio frequency tag on the emergency vehicle is easily detected by the RFID reader. Immediately after the RFID is initialized the barricade in that particular lane opens and the systems distorts the whole system of the traffic lights, turning to green signal so at to give first preference to the lane in which the emergency vehicle is located. At the same time the signal becomes red to the rest of the lanes and the barricades in those lane closes. This method is effective in reducing unnecessary accidents caused by reckless drivers [13].

However, in this work a low cost and compact vehicle accident detection and rescue system is designed to provide a smooth and quick way for the Emergency Medical Service (EMS) to rescue the accident casualties.

METHODOLOGY

The automatic vehicle accident detection and rescue system proposed in this work is shown in Fig. 1. It is a compact IoT-based system, and operates at a low-cost in saving human lives.

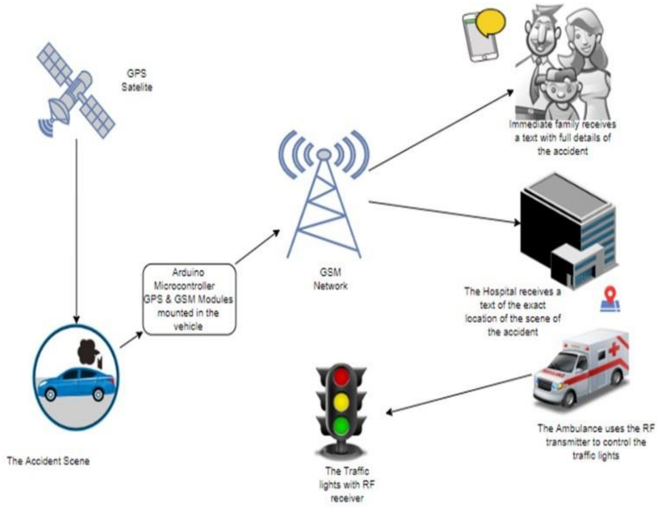

Figure 1: Overview of the automatic vehicle accident detection and rescue system

The automatic vehicle accident detection is an IoT-based project divided into 4 main subsystems namely the accident detector subsystem, Emergency Medical Service (EMS) subsystem, ambulance/EMS vehicle subsystem, and traffic light subsystem.

A. The Accident Detector Subsystem

The accelerometer sensor, buzzer, 16 x 2 LCD, GPS, and GSM modules are mounted in the vehicle making up the accident detection unit as shown in Fig. 2. An MPU-6050 3 Axis Gyro accelerometer sensor was used in this work.

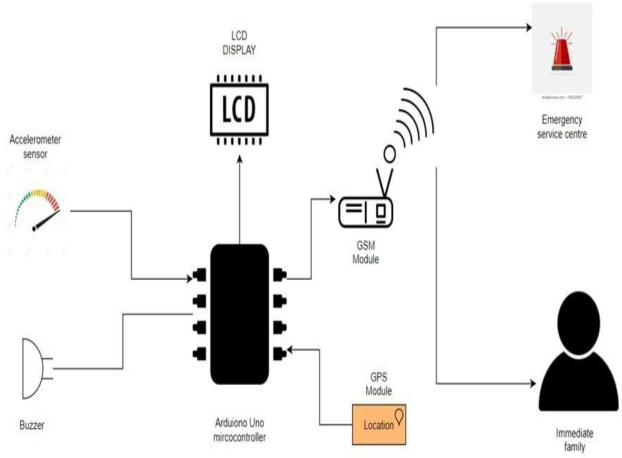

Figure 2: Architectural design for the accident detection and notification segment

The accelerometer detects the crash by measuring the vibration caused during an accident, if it exceeds the threshold value then a signal is sent to the Arduino microcontroller to actuate the notification process. In addition, this sensor detects if the vehicle has fallen into the 3D real axis. The orientation of the accelerometer is shown in Fig. 3.

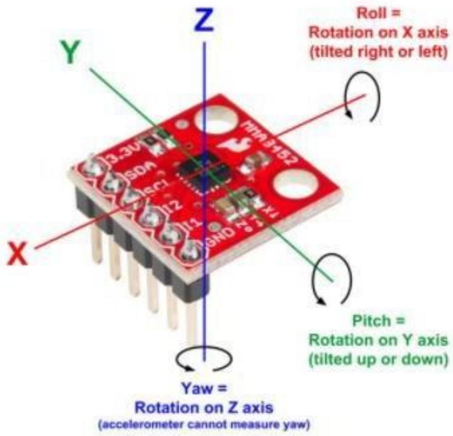

Figure 3. The orientation of an accelerometer

The accelerator is only activated to send forth a signal to Arduino if the angle rises in the X and Y axes go beyond 80 and 70 degrees respectively measure from its zero-degreed original position. It sends a HIGH signal to the Arduino microcontroller to initialise the detection and reporting system. When the Arduino Uno microcontroller receives any signal from any of the above-mentioned sensor, the buzzer rings to confirm the detection of the accident. The Arduino controller then asks the GPS module to collect the latitude and longitude data of the scene of the accident from the GPS. The design also made use of an Nrf24l01 Module for transmitter and receiver, SIM800L GSM Module with inbuilt helical antenna, and another port for a PCB antenna.

A full detailed text message with the exact location of the accident is instantaneously sent to the Emergency Medical Service Centre and the immediate family member with the phone number registered in the system using the low-cost GSM network. The reset button has been incorporated to account for minor and false detections.

B. The Emergency Medical Service Subsystem

The EMS Centre identifies the nearest hospital to the location of the accident from its database and promptly alerts it to send the ambulance to rescue the casualty by finding the quickest route to reach the accident scene or sends its ambulance or rescue vehicles if it is closer to the proximity of the scene of that reported accident. The EMS can be integrated into any country's emergency service system by aligning the communication systems involved.

C. The Ambulance/ EMS Vehicle Subsystem

Figure 3 illustrates the traffic light control using the wireless RF communication system. The EMS centre identifies the nearest hospital to the location of the accident from its database and promptly alerts it to send the ambulance to rescue the casualty by finding the quickest route to reach the accident scene. The emergency vehicle possesses a circuit with push buttons, the RF transmitter, and the Arduino development board. Whenever the emergency vehicle reaches a traffic light during an emergency mode, the system shall manipulate the traffic signal sequence to give first preference to the lane in which the emergency vehicle is. This system is viable only if the emergency vehicle is within a 100 m radius of the traffic junction. If this condition is satisfied the driver shall press the switch button intended for the particular lane that the vehicle is to initiate transmission of a signal from the RF transmitter, which is emitted with the speed of light of 3 $\times 10^{8}$ ms^{-1} at a frequency of 433 MHz. The transmission format is in serial communication. Since the RF communication is a high-frequency network system, the operating distance should not be more than 100 m. This was drawn from the theoretical principle, which states that frequency is inversely proportional to wavelength. However, an RF transmitter with a longer wavelength can be used, but the 100 m transmitter was used in this work due to limited funds for the research. It can be learnt that as frequency increases, the wavelength is decreased hence the RF communication does not function outside the range of (10 – 100 m). This system has 4 push buttons, each representing one of the 4 lanes at a traffic junction. When the emergency approaches a traffic light the traffic light controlling the lane in which the emergency vehicle is shall automatically turn to green to pave way for the rushing emergency vehicle whereas the other 3 lanes are stopped with the red signal.

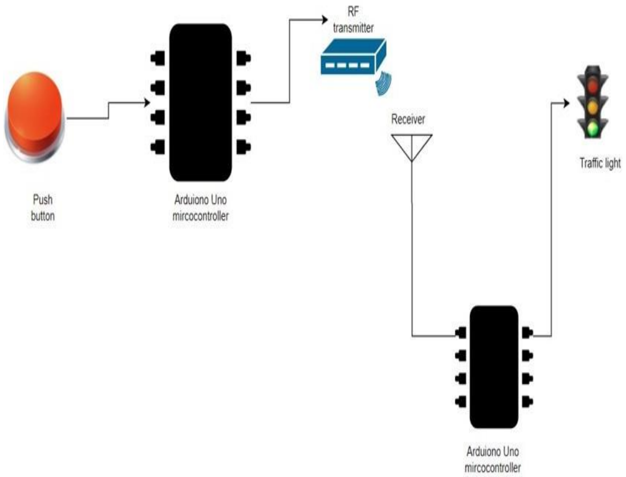

Figure 3: Architectural design for the traffic controller

D. The Traffic Light Subsystem

The traffic lights control the flow of motor vehicles in in a logical and safe order, one lane at a time. However, to allow for quick give-away to the emergency vehicles the RF receiver circuit was connected with traffic lights. The RF receiver accepts the signal transmitted by the RF transmitter in the emergency vehicle and decodes it down so to manipulate the sequence of the traffic signal. The traffic signal controlling the lane in which the emergency vehicle is coming from is automatically changed to a green signal so that the vehicle reaches its destination in time so to save the casualty involved in the accident. The transmitted signal is received by the RF receiver which decodes the transmitted digital bits so to change the sequence of the traffic lights. The lane in which the emergency vehicle is travelling in is given the first preference as the GREEN signal is automatically produced whilst RED signals are sent to the other 3 lanes thus stopping them so to pave way for the rushing emergency vehicle.

This improved smart traffic light system is meant for multiplex lanes and junctions to allow emergency vehicles to reach their destinations in time. The use of the RF technology on the traffic lights is effectively and mostly applicable for use to VIPs such as the presidential motorcade and other important people.

Results and Discussions

Various conditions were created so to examine how the subsystems perform in real-world environments. Analyses were provided to examine if the results obtained are in line with our expectations and the project's specifications.

A. Tilt Measurement Test

An experiment was carried out to examine the tilt angles measurements by the accelerometer sensor thus setting threshold values for accident detection. An accident is assumed to have occurred whenever the threshold values of 80 degrees in the x-axis and the 70 degrees in the y-axis are reached and/or surpassed. Table I shows the number of attempts performed so to investigate the performance of the tilt sensor. The accelerometer sensor met the expected result of displaying the measured angle with a very small error deviation. This error could have been caused by a systematic error in manufacturing.

TABLE I. TILT SENSOR ANGLE ANALYSES

Attempt	Direction	Actual Angle measured by the protractor (degrees)	Angle displayed by the LCD (degrees)	% Error
1	Left	55	54.12	0.016
	Right	66.44	65.01	0.022
2	Left	88.10	87.22	0.010
	Right	65	64.480	0.008
3	Left	100	99.50	0.005
	Right	120	119.12	0.007
4	Neutral	0	0	0.000

Therefore, the tilt sensor shall detect an accident when a car tilts at 80 degrees or more in the x-axis, thus it shall send a HIGH signal to the Arduino to start the reporting process. On the other hand, if 70 degrees is reached or surpassed in the y-axis the reporting system shall be initialised as well. These angles were set as thresholds so to compensate for the alignment of the vehicle in hilly places and uneven ground.

B. GSM Configuration Test

The performance of the GSM in sending text messages to 3 different networks namely Cell-C, MTN and Vodacom was also conducted. The text messages received on 3 chosen networks from a GSM module is shown in Fig. 4 and the response time experienced is shown in Table II. The initial step of configuration was successful as the LED of the GSM module blinked every 3 seconds. From the GSM tests shown above, the response time was varying, but remained within the expected range. This was due to the difference in operational performance of different network providers at different locations.

The GSM used in this experiment performed extremely well as it sends a text message within seconds, this supports the objective of this project to notify the emergency department and the immediate family member registered in the system.

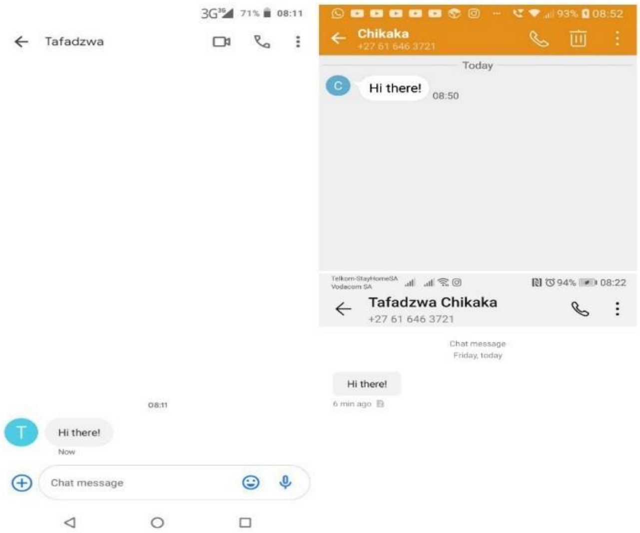

Figure 4: Text messages sent to Cell-C, MTN and Vodacom networks

TABLE II. GSM TEST ON DIFFERENT NETWORK PROVIDERS

Network Name	Attempt Number	Response time (s)	Average Response time (s)
Cell C	1	4	4
	2	5	
	3	3	
MTN	1	6	4
	2	3	
	3	3	
Vodacom	1	2	2.7
	2	4	
	3	2	

C. GPS Configuration Test

The ability of the GPS module in detecting the exact location of an accident was also conducted at 3 different places. Table III the results collected from the GPS module on different sites.

TABLE III. GPS DATA AT DIFFERENT LOCATIONS

Location	Mobile GPS Coordinates		Ublox Neo 6m Coordinates		Comment
	Latitude (South)	*Longitude (East)*	*Latitude (South)*	*Longitude (East)*	
Hursthill	26.187°	27.984°	26.185°	27.984°	Accurate
Melville	26.180°	28.003°	26.178°	26.177°	Accurate
Mayfair	26.200°	28.000°	26.195°	26.196°	Accurate

The results presented in Table III showed infinitesimally error due to deviation in the manufacturing methods of the mobile GPS and the Ublox Neo GPS. The inbuilt antenna facilitated a fast and efficient communication between the module and the satellite in extracting the actual location of any of the tested places in terms of the longitude and latitude results obtained. The objective of locating the scene of the accident using this GPS module was successfully met, as the GPS is supposed to communicate with the Arduino microcontroller by sending it the exact location of the accident scene immediately upon detection.

D. RF Communication Test

The RF transmitter was used to light the LED lights connected with an RF receiver circuit. The results from the experimental circuit were shown in Table IV and are satisfactory. Each push-button action actuated the desired output of the corresponding LED light in a very short period. The Arduino at the transmitter side keeps track of the status of the push button switches. As the switch is pressed a HIGH logic signal is recognised at the analogue inputs of the microcontroller, which encodes the data in preparation of the transmission. The Arduino then propagates the required data to the analogous light on the other circuit on the receiver side in which the particular switch is pressed. The RF receiver receives the propagated data from the transmitter and decodes the data thus effecting a HIGH signal on its pins resulting in the lighting and the switching OFF of the LEDs. As the distance between the RF transmitter and receiver increases, the action was delayed. However, if beyond 100 m, it was dysfunctional according to the device datasheet.

TABLE IV. RF COMMUNICATION TEST RESULTS

Push-button switch number	LED Status
1	Red - ON
2	Red - OFF
3	Green - ON
4	Green – OFF

E. General Performance of the Overall System

An accident is assumed to be detected whenever the threshold values of 80 degrees and 70 degrees in the x and y axes respectively, and the threshold value of 4000 mV/G of sensitivity of vibration is surpassed. When the Arduino receives the HIGH signal of accident detected, the buzzer is actuated, and the LCD shows that an accident has occurred as shown in Fig. 5. The Arduino microcontroller request the exact location longitude and latitude values from the GPS module. The GPS module communicates with the satellite and receives the exact location values of the scene which are transmitted to the microcontroller for display.

Figure 5: Accident detected display

The information from the GPS module is compiled by the GSM so to alert the Emergency Centre and the registered immediate family member. The system reports on the display whenever the message has been successfully sent to the desired destinations. The Emergency Centre and the registered immediate family member receives the notification text message in the following format as shown in Fig. 6. For instance, we assumed that the accident has occurred on 10 Cranswick Road in Sandton. The Emergency Centre use the reported longitude and latitude values so to identify the scene of the accident on Google Maps thus identify the nearest hospital for immediate medical rescue as shown in Fig. 7. In cases such that the emergency centre station might be far off the accident scene the Emergency centre alerts the nearest hospital to provide immediate medical assistance of reaching the victims of the accident.

Figure 6: Alert message format

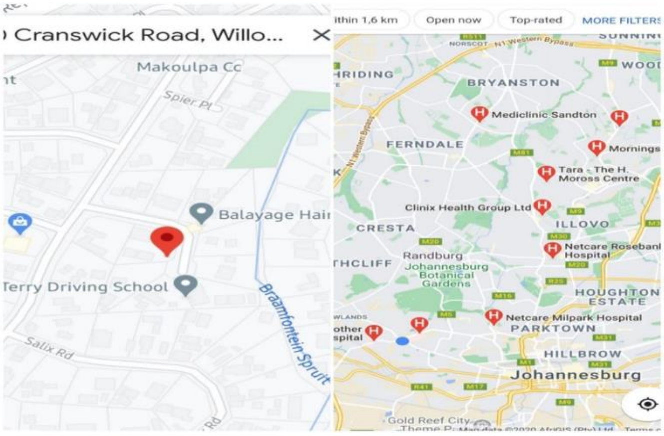

Figure 7: Google Maps used to identify the nearest hospital for immediate rescue

A test on the Accident Detector subsystem was performed at ten different accident locations with results presented in Table V.

TABLE V. GENERAL PERFORMANCE OF THE ACCIDENT DETECTOR SUBSYSTEM

Attempts on different locations	Accident Detected?	Accurate Navigation Status	Text Message Sent Status
1	Yes	Yes	Yes
2	Yes	Yes	Yes
3	Yes	Yes	Yes
4	Yes	Yes	Yes
5	Yes	Yes	Yes
6	Yes	No	Yes
7	Yes	Yes	Yes
8	Yes	Yes	Yes
9	No	Yes	Yes
10	Yes	Yes	Yes

The results shown confirms that the system constructed is viable for its intended use. A 95% accuracy was obtained on the accident detection ability of the system. The navigation and tracking of the location were precisely 97% accurate while the text messaging and green traffic light priority were found to be 100% accurate.

Conclusion

A portable and compact accident detection and alert system which is cost effective was successfully designed and implemented. The system detects accident whenever the set threshold values are surpassed and alerts the emergency responsible authorities and registered next-of-kin within a maximum of 4 seconds. The developed traffic light controller can be applicable to ambulances, fire brigades and other emergency or priority vehicles/convoy. The overall performance of the accident detection and rescue system would help to save the lives of many accident casualties.

A reset button has been incorporated so to disengage the system even in situations that a minor accident occurs so to prevent a wastage of resource especially from the Emergency Centre and reduce panic from the family members. In addition, the operation range need to be maintained within 100 m radius of the traffic light so enhance the good operation of the RF communication. If the driver presses the push button outside the operational range, then no signal shall be transmitted. Finally, interference of the RF signals from other devices might hinder the smooth operation of the wireless RF communication system. The shortcomings of this system are the unpredicted error of false detection at rare cases and the interruption of the RF communication by interference. However, we recommend in future work the use of LoRa transceivers, which supports wireless communication of longer ranges. More so, it is recommendable that this system be improved so to instantaneously shut down the motor vehicle engine upon accident detection for safety reasons of the victims of the accident and also incorporate the ultrasonic sensors which in instances of a possible head-on collision could help to minimize losses of human lives.

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